

Process Safety for Nanotechnology

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Addressing process safety issues when producing nanoscale materials

- Lab-scale plasma reactor
 - Process Hazard Analysis
 - Operating Experience
- Pilot plant plasma reactor
 - Process Hazard Analysis

Nanoscale materials are produced most commonly by 1 of 4 methods:

- vapor deposition
- colloidal
- attrition
- gas phase synthesis

PPG's experience:

- Small-scale plasma reactor at their Allison Park, PA Coatings R&D Center, in use since 2/2003
- In addition, we are working on commissioning a large-scale pilot project

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System components for small-scale plasma reactor include:

- powder feeder system,
- plasma torch,
- reactor,
- bag filters

R&D process for PHAs for this type of system utilizes a Checklist methodology with a team approach and a trained PHA team leader



Potential sources of occupational exposure of nanoscale materials are:

1. Reactor leakage
 - Regular inspection for corrosion
 - Pressure testing
2. Product recovery from bag filters
 - Technician wears a Tyvek suit w/gloves and a full face respirator
 - Two flexible exhaust ducts located near the head

3. Processing and packaging of dry powder
 - Outside of the scope (handled separately)
4. Equipment cleaning and maintenance
 - Procedures in place
 - See also operating history

In addition to IH concerns resulting from releases / exposures, nanoscale material synthesis can have other process safety impacts:

- High temperature
- High pressure

Goal is always to “keep the stuff in the pipes”

Types of controls installed on small-scale lab plasma reactor include:

- Loss of cooling water flow interlocked with plasma torch, stopping all gas flows
- Cooling water temperature monitored and alarmed
- Control system on UPS
- High system pressure interlocked with plasma torch, stopping all gas flows

Types of controls installed on small-scale lab plasma reactor include:

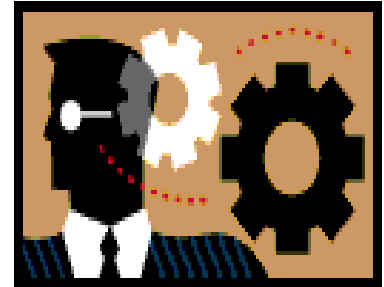
- Relief valve on reactor system
- Rupture disc on cooling tubes

One incident occurred to shut down the system:

- Quench air line failed
- Plasma was released from air line connection
- No injuries

Air line upgraded

For the large-scale pilot plant, we are following a more rigorous series of process risk assessments:



- Preliminary Risk Assessment
- Process Design Risk Assessment
- Detailed Design Review / Risk Assessment

Information to be developed prior to Preliminary Risk Assessment:

- Process chemistry
- Equipment requirements
- Control of reactions
- Chemical compatibility
- Handling of vented and waste materials



Preliminary Risk Assessment elements:

- Review of the literature for previous incidents
- Material hazards
- Inherent safety
- Environmental aspects
- Health and toxicology



Preliminary Risk Assessment elements:

- On-site and off-site transportation
- Facility siting
- External events
- Regulatory reviews
- Identification of codes and standards

Preliminary Risk Assessment elements:

- Organizational and human factors
- Emergency response
- Identification of additional studies that may be needed

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Information to be developed prior to Process Design Risk Assessment:

- Basis for design
- Material and energy balances



- Safe upper and lower operating limits
- Control logic
- Equipment design and materials of construction
- Permitting and IH requirement

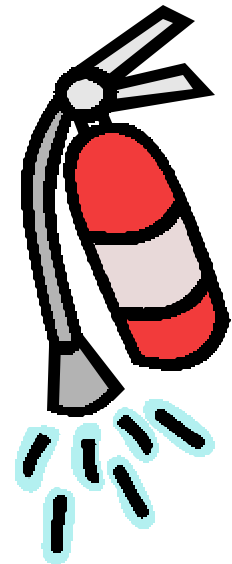
Process Design Risk Assessment:

- Review of status of all prior recommendations
- Development of what-if scenarios for each segment of the process



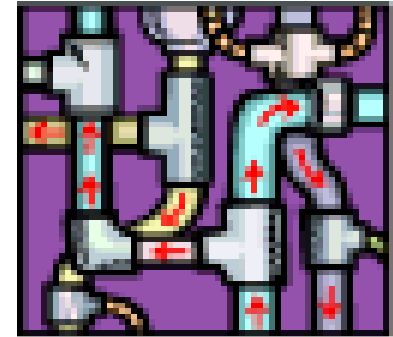
Information required prior to Detailed Design Review / Process Risk Assessment:

- Plant layout
- Equipment specifications
- Fire and emergency response
- Electrical classification
- P&ID for process and utilities



Information required prior to Detailed Design Review / Process Risk Assessment:

- Plot plan
- Tie-in points
- Relief device design
- Safety systems
- Ventilation system design
- Structural design



Design Review / Process Risk Assessment utilizes the HAZOP methodology in most cases

Following this review, insurance review occurs



Where are we in the process:

- Recently completed the Preliminary Risk Assessment
- Planned improvements being considered include:
 - High level detector for loss-in-weight feeder interlocked with conveyor
 - Loss of motion interlocked with conveyor
 - High temperature on gas feed interlocked with feed in case of reverse flow

- Planned improvements being considered include:
 - Isolation between feed systems and reactor
 - Appropriate safeguards for use with other plasma gases
 - Method to prevent moisture in the dry solids feed system (that could cause plugging downstream)

- Planned improvements being considered include:
 - New batch review system to address contamination of incompatibility issues
 - Prevention of reverse flow into utilities
 - Use of oil-free air compressor
 - LEL detectors
 - Guarding of area near plasma torch positive connection

- Planned improvements being considered include:
 - Safe handling of pressure relief
 - Effluent air treatment
 - Waste handling

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These processes are not considered “covered” by process safety regulations but can present “big” hazards

Nanotechnology presents challenges, but these challenges can be handled with the same tools we use for other processes

Rigorous application of process safety concepts is important